VIII. "Reduction of Anemograms taken at Armagh Observatory in the Years 1857 to 1863." By T. R. Robinson, D.D., F.R.S., &c. Received June 11, 1875.

The instrument with which these observations were made is described in the Transactions of the Royal Irish Academy, vol. xxii., and a continuous series of its records exist from 1845 to 1870. With the limited resources of this Observatory it was not in my power to reduce them; but it seemed to some distinguished members of the Royal Society desirable to ascertain whether such observations are competent to develop any laws amid the seeming lawlessness of the winds, and they obtained for me a grant from the Government Fund to discuss the anemograms of these seven years. Unfortunately the work has been long delayed by various accidents.

Of the causes of wind some are undoubtedly periodical; and though they are masked by others of greater magnitude, which, in the present state of our knowledge, seem quite lawless, yet these will disappear from the mean of a sufficient number of observations and leave as residual the first. Of the periodical causes the unequal distribution of heat is the most important; and this, depending on the place of the sun, is evidently a function of the time.

The immediate data of the anemograms, the velocity and direction of the wind, though not the most convenient for combining in great numbers, yet are those which interest most directly the general inquirer; and I have presented them in a Table, which shows for each month of the seven years the mean velocity of the wind in each octant, the number of hours during which it has blown, the maximum in each month, the number of hours above 25 miles, and the number during which the record $=0$. The most striking fact shown by this Table is its extreme irregularity, not merely from octant to octant or month to month, but from year to year. Both velocity and hours are a maximum in the octant S.SW., a minimum in N.NE., their products being as 6 : 1. As to monthly variations, the amount of wind is a maximum in January, decreasing to July in the ratio of $2\frac{1}{4}:1$, and thence increasing to the end of the year, with an exception in the case of March, which is greater than February as 1·13 : 1. This, however, does not establish the common idea of equinoctial gales; for the hours above 25 miles are fewer in March than in February, and there is no excess in September above October. There is also no clear indication of any influence of the solar spots; but for detecting this several decennial periods will be necessary. The annual variations are equally notable. The maximum velocity ranges from 71 in 1861 to 19 in 1860. If the mean velocity for each month be taken without reference to direction, it is 13·51 for January, 4·24 for June, and that for the whole year is 9·73. A mode of discussion which seems more likely to give definite laws is to resolve each velocity into a southern

component S and a western W, to deduce from these interpolation formulæ involving periodic functions of the time for periods of one or more years, and from the changes of these functions in successive periods to derive some general laws. At first sight this might seem impracticable, from the excessive discordance of the values for the same in different years. Thus in the first term of the set, January 1^d 0^h, the extreme difference in the seven years is, for W 20·89, for S 25·35. Evidently single hours were out of the question, and even the mean for the seven years, as was evident from examining their probable errors. However, I meaned each hour for the seven years, then combined these in periods of ten days, but ultimately took their mean for the entire month. These monthly means are given in Table III., from which it appears, first, that all the ultimate values of W and S are positive. This arises from the preponderance of positive over negative values; but the latter occur so frequently that they evidently belong to the wind system; and I was at first disposed to mean and develop them separately. I tried it for January and June, but saw that in the present state of our knowledge it would be useless. In January the negative values are 0·27 of the whole, in June 0·374; and they are found in the septennial means of almost every hour, but so irregularly distributed that it would be almost impossible to develop them in terms of the time. Even were this done, we could not combine in any particular instance the negative and positive results unless we knew the causes which occasionally mix the polar and equatorial currents. I therefore took the entire means as alone available. Secondly, that, as I anticipated, notwithstanding the discordance of the individual observations, the means of from 196 to 217 present a notable agreement, and the differences which they exhibit are subject to law. If we examine the vertical columns (which give the hours of each month), we find in each a principal maximum and minimum and one or more lesser ones. The epochs of these vary with the season. For W in winter the chief maximum is from noon to 3 P.M., in summer from 9 A.M. to noon; for S it varies less, being a little before noon. The principal minimum occurs from 6 P.M. to 10 P.M., both for W and S.

The extreme diurnal ranges are greatest in March, 2·14 and 2·40; least in November, 0·74 and 0·79.

Examining the horizontal columns, which give the monthly variation, the existence of law is still more evident. W has a maximum in January, a minimum in February; its greatest maximum in March, its least minimum in April; a smaller maximum in August, and a smaller minimum in November. The variations are greater here than in the horary columns.

The law for S is simpler: it has one maximum in December and one minimum in July; its range, too, is something greater.

The mean W for the whole seven years $=2·4805$ miles, the mean $S=3·8398$ miles, which give the mean $V=4·5713$, mean $D=32° 54' 44''$, and the actual translation of air 39648 miles.

A Table whose data belong to dates separated by considerable intervals will not give the components generally without interpolation. The formula universally adopted for this when the quantities concerned are periodic functions of the time-angle is that given by Bessel—

$$U_{\theta}=K+A\cos\theta+B\cos 2\theta \text{ \&c.}, +O\sin\theta+P\sin 2\theta \text{ \&c.},$$

or its secondary equivalent—

$$U_{\theta}=K_{0}+K'\sin(\kappa'+\theta)+K''\sin(\kappa''+2\theta)+ \text{ \&c.},$$

where θ is the hour-angle from midnight. But as the monthly variations must also be represented, the coefficients of the first equation must be developed in terms of ϕ (the time-angle from the beginning of the year), and the expression of each of them multiplied by the corresponding cosine or sine of θ. Bessel's computation of the coefficients may be much shortened where, as in the cases before us, the circle is divided into $2n$ equal parts (n being an integer), and the first term of the series $=0$ or $\frac{\pi}{2n}$; for, in consequence of the numerical equality of the cosine and sine of θ, $180+\theta$, $180-\theta$, and $360-\theta$, it is only necessary to compute for the first quadrant. For the horary sets this labour might be shortened by combining them in groups of 3; and the formula for this is given, but it is not quite as exact as the ordinary one, which is also given. The horary constants for W and S, computed by this last, are given in Tables V. and VI. for each month to the fourth order, and an estimate of their precision.

These constants are then developed in month-time, for which the formula is given. This, however, requires a correction; it supposes each u from which it is deduced to belong to a series of ϕ in arithmetical progression. This is not the case: first, the mean of each month does not represent the u belonging to the middle of that month; secondly, the angular distances of the middle of each month from the beginning of the year are not in arithmetical progression. These are both corrected by multiplying the constants by certain factors. The secondary constants so corrected are given in Table VIII. to the 6th order.

As an example of the mode of trying what effect any periodical agent may have on the coordinates, the sun's altitude at Armagh is considered. It is developed in terms of θ, and may probably account for 0·27 of the variation of W and 0·53 of that of S.

The paper concludes with an attempt to show from these observations the existence of an aerial tide-current, which, according to Laplace, is at its maximum 0·195 mile per hour. There was little hope of detecting so small a quantity; but the attempt would at least show how far the mean of a large number of observations may approach the truth. When the moon is east of the meridian its attraction increases W, when west

lessens it; and without attempting to allow for elongation from the sun or declination, I merely compared the Ws at the lunar hours 21 and 3, 9 and 15. I only took the first six months, which seemed sufficient. The result rather surprised me; 2418 observations give for the current 0·0906, which, allowing for the omissions above mentioned and for friction at the earth's surface, must be very near the truth. Among the observations are two above 40 and three above 30; and it seemed worth trying what would be the effect of omitting these and all above four times the probable error of one. In this case for W−W′ it was all above 15. The result is that 2360 observations give 0·0559, showing how little even considerable discordances affect a mean under such circumstances, and also perhaps that even such discordances should not be rejected.

IX. "Preliminary Notice of further Researches on the Physical Properties of Matter in the Liquid and Gaseous States under varied conditions of Pressure and Temperature." By Dr. Andrews, F.R.S., Vice-President of Queen's College, Belfast. Received June 17, 1875.

The investigation to which this note refers has occupied me, with little intermission, since my former communication in 1869 to the Society, "On the Continuity of the Liquid and Gaseous States of Matter." It was undertaken chiefly to ascertain the modifications which the three great laws discovered respectively by Boyle, Gay-Lussac, and Dalton undergo when matter in the gaseous state is placed under physical conditions differing greatly from any hitherto within the reach of observation. It embraces a large number of experiments of precision, performed at different temperatures and at pressures ranging from twelve to nearly three hundred atmospheres. The apparatus employed is, in all its essential parts, similar to that described in the paper referred to; and so perfectly did it act that the readings of the cathetometer, at the highest pressures and temperatures employed, were made with the same ease and accuracy as if the object of the experiment had been merely to determine the tension of aqueous vapour in a barometer-tube. In using it the chief improvement I have made is in the method of ascertaining the original volumes of the gases before compression, which can now be known with much less labour and greater accuracy than by the method I formerly described. The lower ends of the glass tubes containing the gases dip into small mercurial reservoirs formed of thin glass tubes, which rest on ledges within the apparatus. This arrangement has prevented many failures in screwing up the apparatus, and has given more precision to the measurements. A great improvement has also been made in the method of preparing the leather-washers used in the packing for the fine screws, by means of which the pressure is obtained. It consists in saturating the leather with grease by heating it *in vacuo*